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CONTINUOUS CASTING MOLD FOR CASTING MOLTEN METALS, PARTICULARLY STEEL MATERIALS; AT HIGH CASTING RATES TO FORM POLYGONAL BILLET; BLOOM; AND PRELIMINARY SECTION CASTINGS

The invention relates to a continuous casting mold for casting molten metals, particularly molten steel materials, at high casting rates to form polygonal billet, bloom, and preliminary section castings and the like. Said mold is comprised of a tubular mold made of copper whose entry cross-section on the pouring-in side has a cross-section which is enlarged compared to the exit cross-section on the casting exit side and corner radii.

A vastly identical continuous casting mold is known from EP 0 498 296 B2. The underlying objective of this casting mold is to achieve a measurable cooling along the entire circumference of the casting oxide layer within the tubular mold by deforming the casting cross-section, in order to improve the casting quality on the one hand, and increase the casting rate on the other. Furthermore, differences in the casting rate during the operation should be permissible without damaging the castings. This objective is met in the known invention by means of cross-section enlargements in the shape of bulgings which continuously decrease in size. There should be at least three such bulgings across the circumference for round castings.

Such a design is not limited to round castings; however, it cannot simply determine the cooling conditions of the continuous casting, in particular with regard to the surface quality, the near-edge texture structure and the throughput rate of a billet mold.

The performance of such billet molds is also directed towards achieving high surface qualities together with high casting rates.

The difficulties therein result from the complexity of the cooling process and the behavior of the continuous casting on the one hand, and the tubular mold on the other.

The object of the present invention is to adapt such a tubular mold made of copper with regard to all existing technological requirements for the cooling processes at casting rates of approximately 3 - 10 m/min.

The proposed object is met according to the present invention in that the inner geometrical cross-section shape and the corresponding measurements are carried out analogous to the locally deducible quantity of solidification heat for a specified casting rate and analogous to the expansion of the tubular mold. The tubular mold is thereby adapted so as to optimize the process, wherein the solidification heat is dissipated according to a (high) casting rate based on the mold height (mold length) both by means of the casting

contraction behavior as well as the mold expansion during casting operation.

The casting shell always advantageously abuts the inner surface (hot side) of the mold without air gaps. This makes it possible, for example, to take account of the magnified heat quantity in the casting mirror area for casting contraction and mold expansion. Based on these values the tubular mold is designed with regard to its inner form and measurements. The values can be used for example for mold heights of approximately 1000-1100 mm.

The tubular mold can be designed in the same way with regard to its exterior form and measurements, wherein that the exterior form is designed at least in separate height ranges analogous to the mold expansion.

In addition to other criteria the casting material itself is taken into account, in that the tubular mold is shaped with regard to its geometrical cross-sectional forms based on the respective steel grade.

A very pronounced contraction can be measured, for example, in that the tubular mold in the area of the casting mirror exhibits a section of greater conicity in accordance with the greater contraction of the continuous casting.

A conicity is used on such a contraction section which corresponds to the casting shell growth and the typical contraction (on the basis of shell growth S = Key figure k * t; whereas t = casting time), wherein the tubular mold exhibits under the section of greater conicity a continuously varying conicity depending on the casting shell growth and the contraction of the continuous casting.

The conicity of the tubular mold and its wall thickness result among others from the fact that
under the tubular mold section of greater conicity the wall volume is variably designed corresponding to the dissipated heat quantity per unit of time.

The thermal expansion of the tubular mold can also be controlled on its exterior surface by enlarging the exterior surface of the tubular mold in the areas of reduced wall volume by means of notches, ribs or the like.

The behavior of the continuous casting during contraction is among others further advantageously influenced in that, starting at the entry cross-section, a centric, approximately parabola-shaped recess is provided per cross-section side.

Taking into account the decreasing contraction according to the respective casting shell thickness, it is further provided that the approximately parabola-shaped recess declines in the direction toward the casting exit side. This is makes it

possible to carry out an individualized adjustment to the respective broadside and/or edge of the entry cross-section.

Based on exemplified calculations it is further advantageous that the length of the approximately parabola-shaped recess roughly extends into half the mold height.

The contraction behavior of the continuous casting can be further taken into consideration by adapting the length of the approximately parabola-shaped recess to the contraction measure at the height of the respective broadside and/or edge of the mold cross-section.

A further development is achieved in that a plane-parallel surface each is designed in the area of a corner radius which opposes analogous counter surfaces in the inner cross-section form.

The embodiments of the invention are illustrated in the drawings which are described in detail as follows:

Fig. 1 is a cross-sectional view of a tubular mold with a diagram of the solidification heat added across the mold height;

Fig. 2 shows the same cross-sectional view as Fig. 1, wherein Fig. 2A corresponds to "section A-A" and Fig. 2B corresponds to "section B-B";

Fig. 3 shows the same cross-sectional view as Fig. 1, wherein Fig. 3A corresponds to "section A-A" and Fig. 3B corresponds to "section B-B";

Fig. 4 is a cross-sectional view with an approximately parabola-shaped recess, Fig. 4A a "section A-A" and Fig. 4B a "section B-B".

According to Fig. 1 the continuous casting mold is shown in cross-section and serves the casting of molten metals, particularly molten steel materials to form polygonal billet, bloom, preliminary section castings 1 and the like. The continuous casting mold comprises a tubular mold 2 made of copper or of copper alloys.

The entry cross-section 3 on the pouring-in side 4 represents a cross-section enlargement 5 compared to the exit cross-section 6 on the casting exit side 7. The pouring-in side 4 and the casting exit side are continuously provided with a radius 8 (Fig. 4A and 4B) in the transition.
On the right side across the mold height 11 there is a diagram "D" showing the process during the dissipation of solidification heat from the continuous casting 1. The dramatically increasing temperature distribution in the area of the casting mirror results therefrom.

The tubular mold 2 is henceforth built such that the inner geometrical cross-section form 9 and the associated measurements 10 are set analogous to the locally deducible quantity of solidification heat (see Fig. 1, right diagram "D") for a specified (high) casting rate and analogous to the expansion of the tubular mold 2, i.e., designed based on calculations and/or experience.

The exterior form 12 is thereby reduced at least in separate height ranges 12 of the tubular mold 2 analogous to the thermal expansion of the mold.

The values for the expansion or the contraction of casting metals may also be taken into account in the geometrical cross-section form 9 depending on the specific steel grade on hand.

According to Fig. 1 to 4 the tubular mold 2 exhibits in the area of the casting mirror 13 (Fig. 2) a section 14 of great conicity and immediately adjacent a section 15 of even greater conicity corresponding to the greatest contraction of the continuous casting 1.

A continuously varying conicity 16 extends under the section 15 of greater conicity corresponding to the casting shell growth and the contraction of the continuous casting 1. The wall volume 17 is thereby variable or reduced depending on the dissipated heat quantity per time unit. In the areas of

reduced wall volume 17 the exterior surface 18 of the tubular mold 2 is enlarged by means of notches, ribs 19 or the like (Figs. 4A and 4B). These notches 19 are surrounded on the outside by a cooling medium (water) and are located in a common water case (not shown) which surrounds the continuous casting mold. The notches, ribs 19 or the like can also be seen in Figs. 3 and 3B.

In Figs. 4 and 4A a centric, approximately parabola-shaped recess 20 is arranged on each cross-section side 3a starting on the entry cross-section 3. The parabola-shaped recess 20 diminishes in depth and thus in width downwards in the direction toward the casting exit side 7.

The length 20a of the parabola-shaped recess 20 thereby extends approximately into half the height of the mold 11. The length 20a of the parabola-shaped recess 20 is also adapted to contraction measure for the height of the respective broadside and/edge 21 of the mold cross-section 22 (Fig. 4A).

In the area of the corner radius 8 there is each one plane-parallel surface 23 extending downwards, each opposing respective analogous counter surfaces 24 in the inner cross-section form 9.

List of Reference Numbers

1	Billet, bloom, preliminary section casting
2	Tubular mold (made of copper)
3	Entry cross-section
3a	Cross-section side
4	Pouring-in side
5	Cross-section enlargement
6	Exit cross-section
7	Casting exit side
8	Corner radius
9	Geometrical cross-section form
10	Measurement
11	Mold height
12	Exterior form
13	Casting mirror
14	Section of great conicity
15	Section of greater conicity
16	Varied conicity
17	Wall volume of the tubular mold
18	Exterior surface of the tubular mold
19	Notches, ribs
20	Parabola-shaped recess
20a	Length of the recess
21	Broadside and/or edge
22	Mold cross-section
23	Plane-parallel surface
24	Identical counter surface